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Overwinter Mortality of Trout in Temple Fork of the Logan River

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DANIEL RICHARD CERVEN

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by

Daniel Richard Cerven

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of

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Approved:

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Major Professor

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Daniel Richard Cerven

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ABSTRACT

Overwinter Mortality of Trout in Temple Fork

of the Logan River

by

Daniel Richard Cerven, Master of Science

Utah State University, 1973

Major Professor: Dr. Robert H. Kramer
Department: Wildlife Resources

The objectives of this study were to determine the mortality rates of trout in Temple Fork of the Logan River during the winter of 1970-1971 and to identify factors related to trout mortality.

Trout in seven 100-m sections of the 7.3-km stream were sampled by electroshocking in October, December, February, and April. Captured trout were weighed, measured and tagged or fin-clipped. Scale samples were taken for age determinations and the fish were returned to the creek.

Water temperature, snow cover, and anchor ice were monitored.

Three species of trout were found in Temple Fork; brown, rainbow, and cutthroat trout. Daily instantaneous mortality rates were calculated for both marked trout and estimated numbers in the stream.

Daily instantaneous mortality rates, $\underline{i}$, ranged from 0.01136 to 0.06796 in marked brown trout and from -0.00964 to 0.04790 in estimated numbers of brown trout. Mortality rates were significantly different among

age groups in both marked (0.025 level) and estimated numbers (0.25 level) of fish. Anchor ice was found to be a significant factor related to the mortality of Age Group O brown trout. A decrease of 97 percent was found in the estimated numbers of all age groups of brown trout from October, 1970 to April, 1971.

Daily instantaneous mortality rates, $\underline{i}$, ranged from 0.01292 to 0.02833 in marked rainbow trout and -0.01175 to 0.05536 in estimated numbers. Mortality rates were not significantly different among age groups or sampling periods and anchor ice and snow cover were not significant factors. A decrease of 45 percent was found in the estimated numbers of all age groups of rainbow trout from October, 1970 to April, 1971.

Daily instantaneous mortality rates of marked cutthroat trout ranged from 0.00000 to 0.04699. In estimated numbers the rates ranged from -0.00837 to 0.06294. Mortality rates were significantly different (0.25 level) among sampling periods but not among age groups in the estimated numbers of fish. The estimated numbers of cutthroat trout of all age groups decreased by 73 percent from October, 1970 to April, 1971.

(77 pages)

INTRODUCTION

Since the study of mortality is basic to the understanding of the dynamic interactions of fish and environment in an area, some knowledge of the amounts and causes of mortality is necessary before other studies, such as productivity, migration, or the effects of environmental alterations can be made. Temple Fork of the Logan River is being considered as an experimental stream by the Utah Cooperative Fishery Unit and the data obtained from this study will be used in conjunction with other studies to obtain a better understanding of the stream ecosystem to better evaluate various management practices.

Basically there are two types of mortality: that due to natural conditions and that due to fishing. This study was concerned with natural mortality during the winter when the fishing season was closed. Overwinter mortality of trout in streams has been studied in a few areas, the most notable of which is the Sierra Nevada Aquatic Research Laboratory on Convict Creek in California. However, there have been no studies in the Intermountain West, that area occupied by the States of Utah, Nevada, Idaho, and portions of Wyoming and Colorado.

Generally winter mortality is attributed to severe physical conditions. Studies of the relationship between winter mortality and stream

foods in Convict Creek from 1952 to 1956 have revealed that food supply was not a critical factor in the mortality of brown trout (Salmo trutta) and rainbow trout (Salmo gairdneri), since digestion is very slow at low temperatures (Reimers, 1957). Needham and Slatter (1944) found that ice formations and subsequent melting altered the flow of Convict Creek to such an extent that high mortalities were noted in hatchery-reared brown trout, wild brown trout, and hatchery-reared rainbow trout. Other factors influencing mortality in Convict Creek were found to be the formation of anchor ice which blocked side-channel stream flow thereby stranding the fish (Needham, Moffett, and Slatter, 1945; Maciolek and Needham, 1951) and falling snow banks which either crushed trout directly or stranded them by the formation of temporary dams (Needham and Slatter, 1944). Nielsen, Reimers, and Kennedy (1957) found that mortality of rainbow trout was highest during the time that water temperatures were rising and that all mortality was due to a secondary fungus infection on abraded areas of the skin.

The studies by Needham, Moffett, and Slatter (1945), Maciolek and Needham (1951), and Needham (1947) all revealed that overwinter mortality was 50-60 percent in both rainbow and brown trout. However, Needham, Moffett, and Slatter (1945) found that larger brown trout experienced greater overwinter mortality than smaller trout, whereas Needham (1947) found that mortality was approximately the same for all ages and sizes.

In studies of brook trout (Salvelinus fontinalis) for 11 years in Lawrence Creek, Wisconsin, Hunt (1969) found that mortality during the

first winter of life ranged from 28 to 65 percent and that mortality decreased with increased size and higher water temperature. Hunt also felt that lower mortality among larger fish was primarily due to greater resistance to low temperature-induced stress.

The objective of this study was to examine the overwinter mortality of brown, rainbow, and cutthroat trout (Salmo clarki) in Temple Fork of the Logan River. The specific objectives were:

1. To determine the mortality rates of trout in Temple Fork during the winter of 1970-1971.
2. To identify factors related to trout mortality.

STUDY AREA

Location

Temple Fork of the Logan River is a small mountain stream which begins at a large spring approximately 2000 m above sea level and flows northwest for 7.3 km before emptying into the Logan River, 35 km northeast of Logan, Utah. The stream is wholly within Cache National Forest and the lower 5.3 km are accessible by a dirt road. The remaining 2 km can be reached by a footpath which parallels the stream.

Geology and Topography

The stream may be divided into six basic sections on the basis of the topography of the area. For the first 1.54 km below the source, the stream flows through a steep canyon. The stream then flows for 2.00 km through a relatively flat plateau before entering another canyon-like area. This area continues for 1.30 km after which the stream enters another plateau. After 1.80 km the stream then flows through another canyon for 0.55 km. For the remaining 0.15 km the stream flows through a relatively level area from which it enters the Logan River.

The uppermost portions of Temple Fork run through three main geologic formations, the Nounan, Bloomington, and St. Charles (Williams,

1948). In general these are composed primarily of limestones and dolomites with some shale and quartzite. The composition of the lower areas consists of a great degree of alluvium from glacial deposits. Again there is also a large amount of limestones along with some conglomerates (Williams, 1948).

Sampling Areas

Seven 100-m sections of the stream were selected for fish sampling and were chosen as representative of the basic topography of the stream (Figure 1). In order to facilitate repeated samplings, the 100-m fish sampling sections were further divided into stream units based on the physical divisions in the stream (such as dams, culverts, log jams, etc)(Table 1).

Table 1. Locations, areas, and number of stream units of fish sampling sections, Temple Fork; October, 1970-April, 1971

Section	Distance From Mouth (km)	Area (m^2)	Number of Stream Units
I	6.90	287.0	5
II	5.65	365.2	7
III	4.50	416.0	6
IV	3.00	274.5	7
V	1.60	405.9	5
VI	0.46	387.8	7
VII	0.01	350.9	6

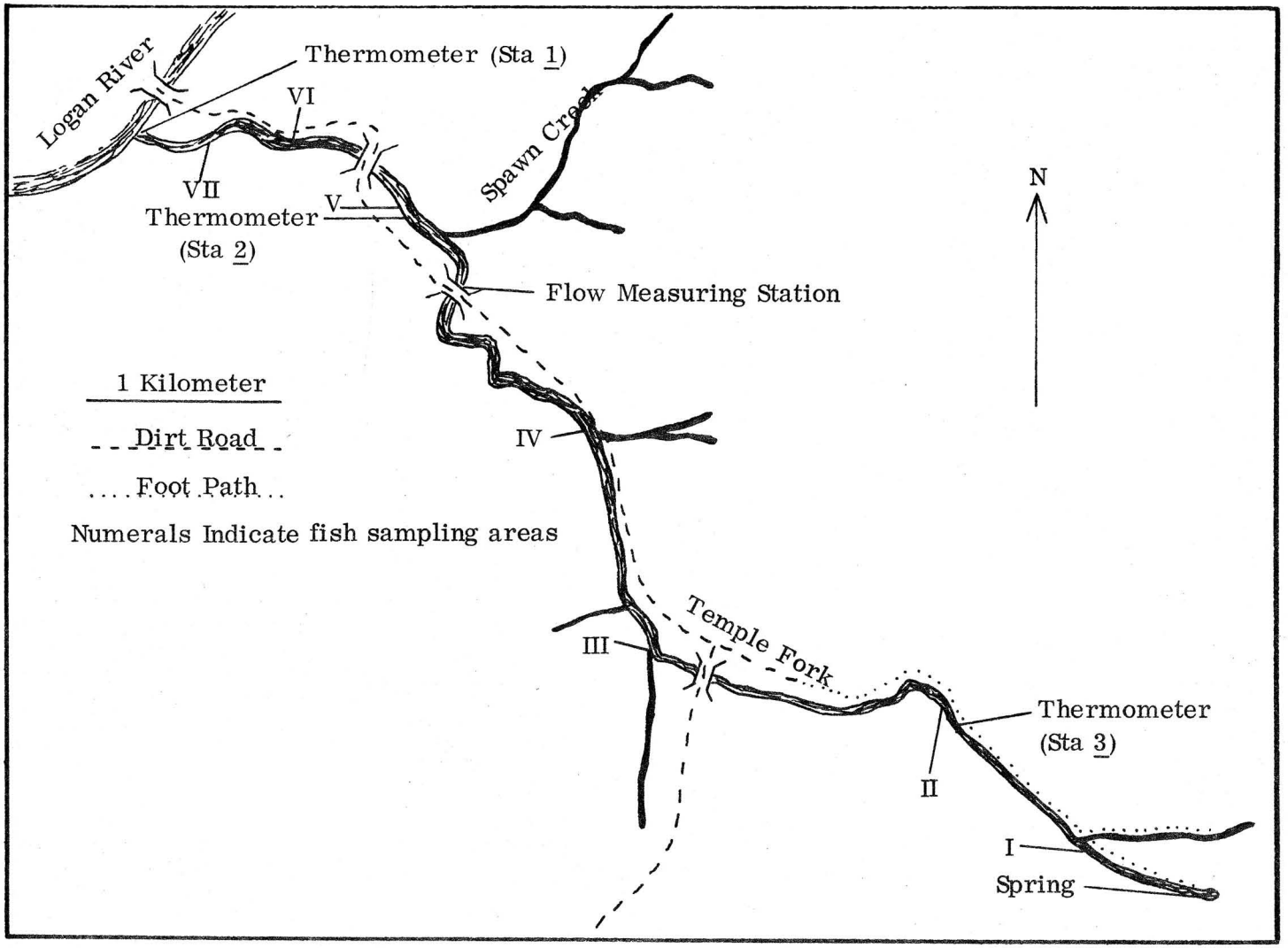

Figure 1. Map of Temple Fork showing sampling sections I-VI, regarding thermometer locations and the flow measuring station, 1970-71.

MATERIALS AND METHODS

Water temperatures were recorded with three Ryan, continuous reading, submersible thermographs from November 17, 1970 to April 29, 1971. The thermographs were located approximately 10, 1800, and 5500 m from the mouth of Temple Fork. Estimates of daily mean water temperatures were made by averaging the daily maximum and minimum temperatures.

Stream discharge was determined at weekly intervals from November 20, 1970 to March 27, 1971 (17 determinations). Current velocity was measured at 30.5 cm (one foot) intervals across the stream with a Gurley current meter at a culvert 2.1 km from the mouth of the stream. Water depth was recorded at 15.2 cm (6 inch) intervals at the same time and location and the partial cross-sectional areas determined. The volumes of flow through each partial cross-section were summed to obtain total discharge.

Alkalinity (methyl orange and phenolphthalein), pH, and dissolved CO_2 were measured at monthly intervals (five determinations) with a Hach Water Analysis Kit. Conductivity readings were taken at weekly intervals with an Industrial Instruments RB 3 Solu Bridge conductivity meter (only eight weekly conductivity measurements were made due to an accident

which damaged the conductivity meter). These measurements were taken at the thermograph sites.

Observations of snow depth and air temperature were made at the Utah State University Forestry Summer Camp located approximately 6.4 km along the Logan River above the mouth of Temple Fork and at an altitude approximately 152 m higher. The data were provided by Mr. Thomas Quigley of the Forest Science Department at Utah State University. Snow depth was measured with a Mount Rose Snow Tube. Air temperatures were measured with a maximum-minimum current thermometer mounted in a Stevensen Screen.

Fish populations were sampled in the fish sampling sections in October and December, 1970 and February, 1971 by electrofishing. The April, 1971 sampling included almost the entire stream as well as portions of the Logan River. A 115-volt, 60-cycle, a.c. alternator connected to a variable voltage pulsator (d.c.) was used. Direct current with one negative and one positive electrode was used to capture the fish. Before being returned to the stream, each fish was anesthetized with MS-222 (except in April), weighed, measured (total length), and most had scales removed for age determinations. In some cases during the April sampling only the length was measured or the fish was examined for tags or fin clips solely. Larger specimens were tagged with individually numbered streamer tags according to the method of Dell (1968). Smaller fish were fin-clipped.

In order to estimate populations within the stream, the smaller stream units were sampled repeatedly on the same day until no additional fish were captured. The population in each fish sampling section was then determined by summing the numbers captured in each of the smaller stream sections. In October, December, and February the number of fish actually captured was considered to be the entire population of that section since the repeated sampling of the stream units showed no additional fish present. Since the total number of sections represented approximately one-tenth of the entire stream, the number of fish caught was multiplied by 10 to estimate the number of fish of each species in the entire stream. I assumed that the size, age, and species composition in each section was representative of the entire stream and biomass and mortality rates were calculated from these data. The estimates from the April sampling were based on repeated samplings of four 100-m sections of stream and visual counts of fish missed during the entire operation. This deviation from the previous sampling techniques was due to the lack of personnel.

The length and weight data were used in the determinations of length-weight relationships, conditions, factors, and length-frequency distributions. For fish captured in April and not weighed, their weight was calculated from the length-weight relationship. Age was determined from scales taken from the left side of the fish between the dorsal fin and the lateral line. Scales were read with a stereoscopic dissecting

microscope and verified through comparison with length-frequency distributions. In some cases scales were not taken and the age was determined from fish length.

Since the slopes of the regression lines representing the length-weight relationships in the three species were not significantly different from 3, the condition factor used in this study was the K factor, which was calculated from the formula:

$$K = \frac{W}{L^3} \times 10^5$$

RESULTS

Physical and Chemical Characteristics

Water temperature

Mean monthly water temperatures ranged from 2.3° C (Station 2; December) to 5.6° C (Station 1; April) (Table 2). Daily mean water temperatures ranged from 0° C (Station 2; January 5, 1971) to 7.5°C (Station 1; April 30, 1971).

Table 2. Mean monthly water temperatures (°C) from three locations in Temple Fork; November, 1970-April, 1971.

Month	Station 1	Station 2	Station 3
November, 1970	-	3.7(14)	4.1(14)
December	-	2.3(30)	4.4(30)
January, 1971	3.5(15)	2.6(30)	4.9(30)
February	2.9(27)	2.5(27)	-
March	4.3(30)	3.7(25)	-
April	5.6(29)	5.2(29)	4.8(28)

Numbers in parentheses are the number of daily readings used to calculate the average for each month.

Flow

During the study period, water flow ranged from 0.236 m^3/sec (March 8, 1971) to 0.416 m^3/sec (March 27, 1971) (Table 3). The average of the 17 determinations was 0.309 m^3/sec.

Table 3. Volume of flow, Temple Fork; November, 1970-April, 1971

Date	Time (Hrs)	Volume of Flow (m^3/sec)
Nov. 20, 1970	1130	0.292
Nov. 27	1245	0.334
Dec. 11	1015	0.315
Dec. 20	1210	0.342
Dec. 27	1230	0.361
Dec. 31	1255	0.283
Jan. 9, 1971	1315	0.274
Jan. 16	1330	0.308
Jan. 23	1300	0.328
Jan. 30	1215	0.274
Feb. 5	1330	0.279
Feb. 12	1300	0.384
Feb. 20	1515	0.316
Mar. 8	1215	0.236
Mar. 14	1150	0.291
Mar. 20	1230	0.312
Mar. 27	1030	0.416

Conductivity

The conductivity determinations were terminated on January 23, 1971 due to an accident which damaged the conductivity meter. Throughout the period during which these measurements were taken, the conductivity varied from 295 μmho/cm (Station 3; November 27, 1970) to 365 μmho/cm (Station 2; November, 1970) (Table 4). Mean conductivity for each Station (1, 2, and 3) was 335, 330, and 304 μmho/cm. The greatest variance (s^2) was found in Station 2 and the least in Station 3.

Table 4. Conductivity (μmho/cm) at three locations in Temple Fork; November 16, 1970-January 23, 1971

Date	Station 1	Station 2	Station 3
Nov. 16, 1970	340	320	300
Nov. 27	345	365	295
Dec. 11	340	335	305
Dec. 27	-	320	300
Dec. 31	340	325	300
Jan. 9, 1971	320	325	-
Jan. 16	340	330	310
Jan. 23	-	330	310

Carbon Dioxide

No free CO_2 was found at any time during the study period (Table 5).

Total alkalinity

Total alkalinity ranged from 140 (November 16, 1970) to 170 (December 11, 1970 and March 14, 1971) ppm $CaCO_3$ with a mean of 158 (Table 5).

pH

The pH varied from 8.0 (January 16, 1971) to 8.7 (December 11, 1970). The mean pH of the five samples was 8.3 (Table 5).

Table 5. Monthly determinations of free CO_2, total alkalinity, and pH taken 2100 m from the mouth of Temple Fork

Date	CO_2 (ppm)	Alkalinity (ppm $CaCO_3$)	pH
Nov. 16, 1970	0	1.4	8.4
Dec. 11	0	170	8.7
Jan. 16, 1971	0	153	8.0
Feb. 12	0	150	8.2
Mar. 14	0	170	8.4

Table 6. Mean monthly air temperatures (oC) recorded at the Utah State University Forestry Summer Camp, October, 1970-March, 1971

Month	Mean Temperature	Range
Oct. 1970	2.2	-8.9 to 12.8
Nov.	-0.8	-5.0 to 4.5
Dec.	-6.5	-12.2 to 3.9
Jan., 1971	-5.5	-23.4 to 3.9
Feb.	-5.4	-12.2 to 2.2
Mar.	-4.0	-16.1 to 4.5

Anchor ice

Pearson (1970) found that anchor ice formed in the lower portions of Temple Fork when air temperatures dropped below -18°C. Observations of anchor ice were made at varying intervals throughout this study on each of the 100-m fish-sampling sections and percentages of the area of each section covered by anchor ice were estimated. Air temperatures dropped below -18°C only twice during my study: January 3-6 and March 1-2, 1971. However, anchor ice was seen in Sections V and VII on January 16 and February 20, 1971; indicating that anchor ice will form in Temple Fork at temperatures as high as -12.2°C. An anchor ice index was calculated for the interval between fish-sampling dates by multiplying the number of days in each period that the stream bottom was covered by the percentage of the area of each section covered.

Anchor ice was found in only the lower four sampling sections (Table 7). The index ranged from 0 in all of the sections during the October to December period and in Section IV during the February to April period to 255 in Section V during the December period. During January 3-6, 1971, anchor ice clogged the stream to such an extent in the area between Sections V and VI that the flow of water was forced completely out of its channel.

Table 7. Anchor ice indices* for four 100-m sections of Temple Fork; October, 1970-April, 1971

Period	Section			
	IV	V	VI	VII
Oct. -Dec.	0	0	0	0
Dec. -Feb.	20	255	120	210
Feb. -Apr.	0	15	10	30

*Indices calculated by multiplying the number of days in each period by the percentage of the area of each section covered.

Snow depth

Snow depth (recorded at the Utah State University Forestry Summer Camp) ranged from a weekly high of 135.76 cm on January 16, 1971 to a weekly low of 7.87 cm on April 17, 1971 which was the last reading before the snow had completely melted (Table 8).

Table 8. Snow depth measurements (average of 10 readings) in cm taken at the Utah State University Forestry Summer Camp from December 11, 1970 to April 17, 1971

Date	Depth (cm)	Date	Depth (cm)
Dec. 11, 1970	42.00	Feb. 18	90.42
Dec. 19	55.37	Feb. 25	108.71
Dec. 24	60.58	Mar. 6	103.51
Dec. 30	70.38	Mar. 13	91.09
Jan. 7, 1971	63.88	Mar. 18	108.08
Jan. 16	135.76	Mar. 25	97.03
Jan. 21	95.63	Apr. 3	74.17
Jan. 28	91.31	Apr. 11	36.07
Feb. 4	86.36	Apr. 17	7.87
Feb. 11	87.38		

Snow cover

Observations of snow cover were made at varying intervals throughout the study period on each 100-m fish-sampling section. Percentages of the area of each section covered by snow were estimated. A snow cover index was calculated for the time between fish sampling dates by multiplying the number of days in each period that the stream covered by the percentage of the area of each section covered.

The snow cover index ranged from 70 in Section II during the October to December period to 1953 in Section I during the December to February period (Table 9).

Table 9. Snow cover indices[1] for seven 100-m sections of Temple Fork; October, 1970-April, 1971

Section	Period		
	Oct. -Dec.	Dec. -Feb.	Feb. -Apr.
I	360	1953	1525
II	70	275	153
III	90	506	201
IV	113	506	201
V	90	732	201
VI	158	979	153
VII	90	550	201

[1]Indices calculated by multiplying the number of days in each period by the percentage of the area of each section covered.

Fish Distribution and Mortality

Four species of fish were captured in Temple Fork; brown, rainbow, cutthroat, and brook trout. However, only one brook trout was captured and five rainbow--cutthroat trout hybrids were captured. Due to the relative scarcity of brook trout and hybrids, they were not included in the analyses.

Mortality for each species and age group was expressed as $\underline{i}$, the daily total instantaneous mortality rate (Ricker, 1958). The $\underline{i}$ values were calculated from the equation:

$$\underline{i} = \frac{\text{Log}_e N_o - \text{Log}_e N_t}{t};$$

where N_o = number of fish at the start of the period; N_t = the number at the end of the period; and t = number of days in the period. For the purpose of the calculations, the middle of each of the sampling dates was used in determining t (Table 10).

Table 10. Middle dates of each fish sampling and the number of days in each sampling period (t), Temple Fork; October, 1970-April, 1971

Period	Middle Dates	Number of days in Each Period (t)
Oct. - Dec.	Oct. 24, 1970 Dec. 22, 1970	59
Dec. - Feb.	Dec. 22, 1970 Feb. 15, 1971	55
Feb. - Apr.	Feb. 15, 1971 Apr. 17, 1971	61

Two series of instantaneous mortality rates (i) were calculated from the data on each species and age group. First, mortality rates were calculated for only those fish which were tagged or fin-clipped and secondly, mortality rates were calculated from estimated numbers of fish in each section.

Due to a lack of time and personnel, many of the fish captured in April were not weighed or measured and others were only measured.

The age of the measured fish was determined by comparing the length to the length-frequency distribution of the same species of known age. The weight was calculated from the length-weight relationship of earlier samples. In the case of the fish which were not measured, the age was calculated from a proportion based on the age distribution of fish caught which were aged from scale samples taken during the April sampling.

Effects of handling and tagging on mortality

During the February sampling, approximately 75-m of the creek immediately below Sampling Section V was electroshocked and four cutthroat trout were captured, anesthetized, measured, and three were tagged and one fin-clipped. Scale samples for age determinations were also taken. These fish were then placed in a live cage in the stream for five days. None of the fish died and all were released in the section from which they were taken.

Brown trout

Brown trout were the most numerous of the three species and constituted 66, 64, 43, and 16 percent of the fish captured in the October, December, February, and April samplings (Table 11).

While 109 brown trout were actually captured during the October sampling, 1090 was the estimated population of brown trout of all age groups since only 10 percent of the entire stream was sampled.

Table 11. Estimated number, estimated weight (kg), percent composition, and estimated standing crop (kg/ha) of brown trout in Temple Fork; October, 1970-April, 1971

Date	Number	% of Total Number	Weight (kg)	% of Total Weight	Standing Crop (kg/ha)
Oct.	1090	66	37.9	46	16.4
Dec.	510	64	17.2	35	7.4
Feb.	170	43	6.9	19	3.0
Apr.	38	16	6.3	20	2.7

Length-frequency distribution. The calculated length-frequency distributions for brown trout were made on the averages of groups ranked in 25-mm total lengths (Figures 2 and 3).

Age group O brown trout were the most numerous fish captured in October, December, and February. In October their total length ranged from 35 to 96 mm. In December the range was from 35 to 106 mm and in February these fish ranged from 36 to 100 mm. Five age group O brown trout were captured in April but not measured.

Three age group I brown trout were captured in October and ranged in length from 165 to 172 mm. Brown trout of age group I were not found during the remainder of the study.

Age group II brown trout were 210-290 mm long in October; 202-274 mm in December; 253-258 mm in February; and 188-275 in April. A

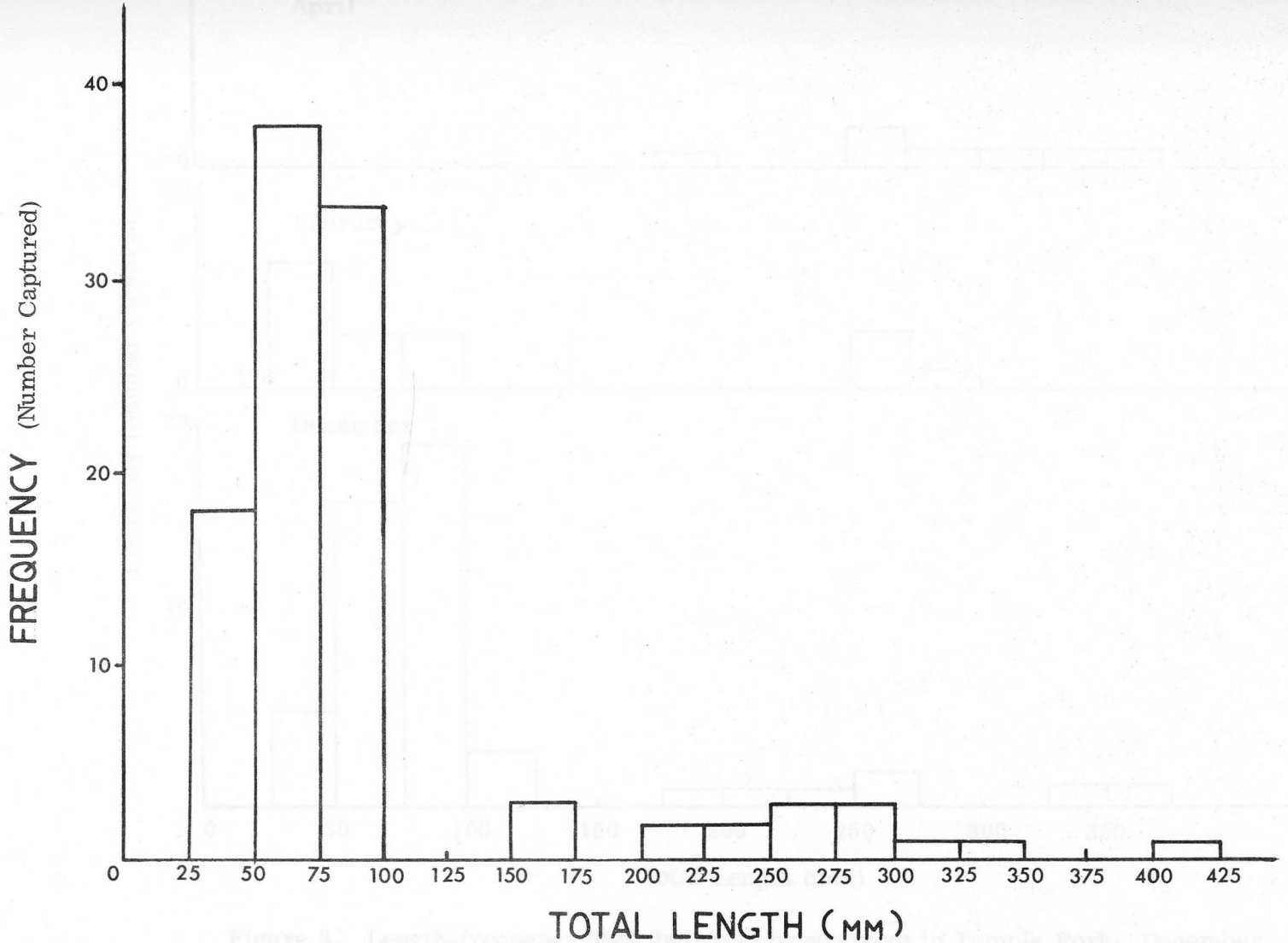

Figure 2. Length-frequency distribution of brown trout captured in Temple Fork; October, 1970.

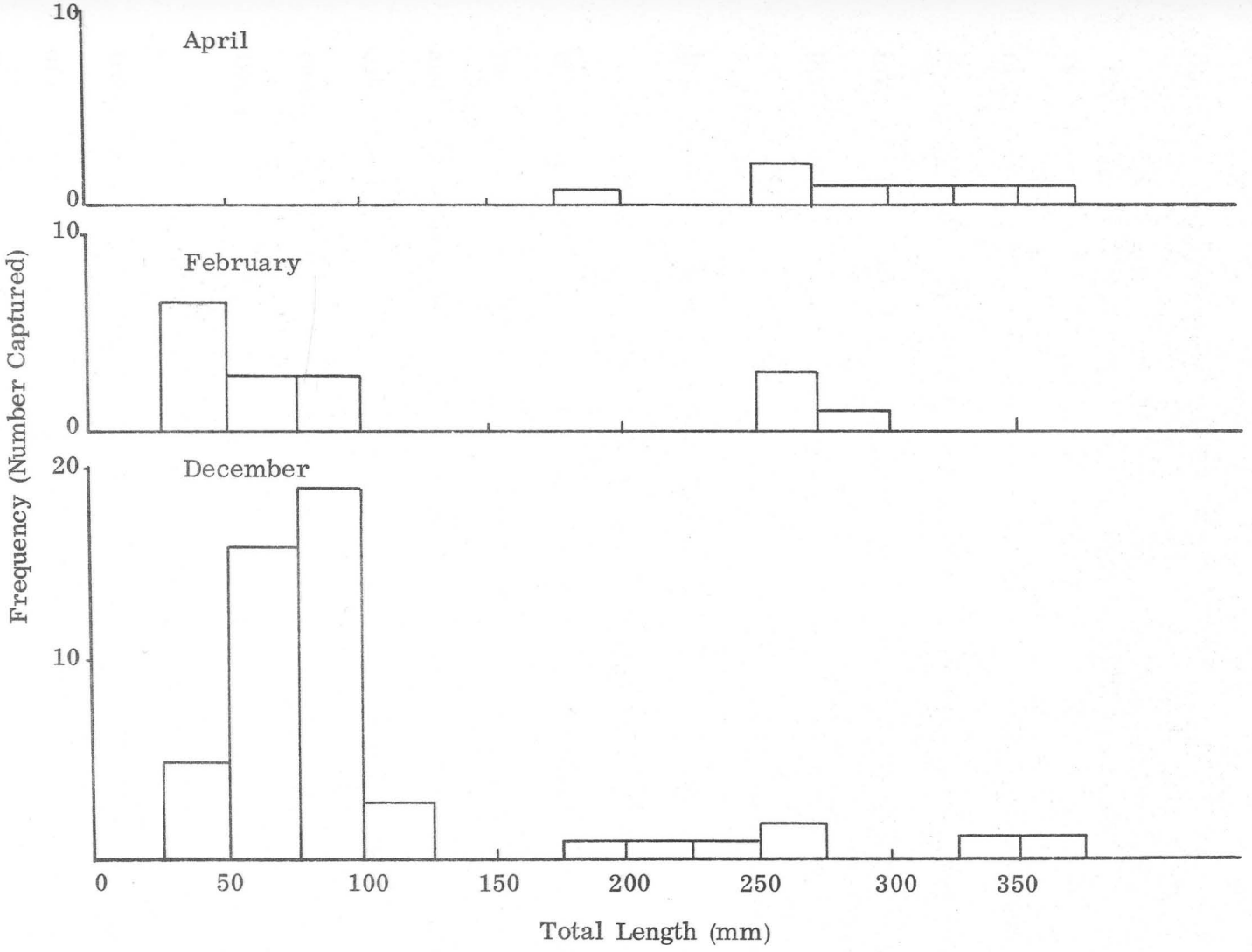

Figure 3. Length-frequency distribution of brown trout in Temple Fork; December, 1970; February, 1971; and April, 1971.

total of nine was captured in October, four in December, three in February, and four in April. However, of the 14 unmeasured brown trout captured in April, six were considered to be age group II.

During the first three samplings, age group III brown trout were relatively scarce. The two trout caught in October were 309 and 335 mm in length. In December, the two captured were 331 and 351 mm. Only one age group III brown trout was captured in February and was 294 mm long. In April. six were captured and aged. They ranged from 296 to 371 mm in length.

Only one age group IV brown trout was captured during the study. It was 411 mm long and taken in October.

Length-weight relationship. The length-weight relationship was calculated on the averages of groups ranked in 25-mm total lengths of all fish taken in October, December, and February. Fish captured in April and weighed were also used but for those which were only measured, the calculated relationship was used to determine their weights. The calculated length-weight relationship was: Log W = -4.63413 + 2.84258 Log L.

Condition factors. K factors were calculated for all brown trout which were both weighed and measured using the reciprocal method of Carlander (1950). The mean K factors of age group O-III brown trout fluctuated from 0.97 in April to 1.49 in December (Table 12).

Table 12. Mean condition factors of brown trout captured in seven 100-m sections of Temple Fork; October, 1970-April, 1971 (Sample size in parentheses)

Age Group	Section	Month			
		October	December	February	April
O	I	-	-	-	-
	II	-	-	-	-
	III	-	-	-	-
	IV	1.26(1)	1.00(1)	1.44(7)	-
	V	1.30(38)	-	0.96(3)	-
	VI	0.93(26)	1.04(11)	0.87(2)	-
	VII	1.17(28)	1.76(32)	0.76(1)	-
	All	1.16(93)	1.56(44)	1.19(13)	-
I	I	-	-	-	-
	II	-	-	-	-
	III	-	-	-	-
	IV	-	-	-	-
	V	1.08(3)	-	-	-
	VI	-	-	-	-
	VII	-	-	-	-
II	I	-	-	-	-
	II	-	-	-	-
	III	1.00(2)	-	0.93(1)	-
	IV	-	0.96(1)	-	-
	V	1.04(5)	0.99(1)	0.88(1)	-
	VI	1.11(2)	-	-	-
	VII	1.05(1)	0.90(2)	-	-
	All	1.04(9)	0.94(4)	0.91(2)	0.96(4)*
III	I	-	-	-	-
	II	-	-	-	-
	III	1.11(1)	1.03(2)	0.85(1)	-
	IV	-	-	-	-
	V	1.06(1)	-	-	-
	VII	-	-	-	-
	All	1.09(2)	1.03(2)	0.85(1)	0.97(6)*
All	All	1.15(212)	1.49(100)	1.13(32)	0.97(10)*

*Condition factors calculated for trout captured in the entire creek.

Movement of marked brown trout. The only sizable recovery of marked fish was in age group O and was confined to Section VII. Of the 25 trout which were adipose-clipped in October, six were recovered in December in the same section.

The longest movement of any fish recaptured in this study was by an age group II brown trout. The fish was captured in Section V during the October sampling and was recaptured in the Logan River approximately one-km upstream from the mouth of Temple Fork in April. It had moved a net distance of 2.6 km.

Mortality. The estimated numbers of brown trout decreased from a total (for all age groups) of 1090 in October to 38 in April, a decrease of 97 percent; much higher than the mortality found in other investigations (Needham, Moffett and Slatter, 1945; Needham, 1947; Maciolek and Needham, 1951; and Nielson, Reimers, and Kennedy, 1957). Age group O fish exhibited a decrease of 99.3 percent, age group I, 100 percent, age group II 87 percent, and age group III 10 percent.

Daily instantaneous mortality rates, i, of marked brown trout ranged from 0.01136 (Age Group III, Feb.-Apr.) to 0.06796 (Age Group O, Dec.-Feb.) (Table 13). The i values of marked brown trout in each of the five, 100-m sampling sections in which they were found is given in Table 14. These mortality rates ranged from 0.00000 (Age Group II, Section VII, Oct.-Dec.; age group II Section III, Dec.-Feb.; and age group III, Section III, Dec.-Feb.) to 0.06301 (age group O, Section VII, Dec.-Feb.).

Table 13. Daily instantaneous mortality rates, i, of marked brown trout in Temple Fork; October, 1970-April, 1971

Period	Age Group				
	O	I	II	III	IV
Oct.-Dec.	0.04646	0.02350	0.02041	0.01175	0.01175
Dec.-Feb.	0.06796	0.01260	0.01260	0.01260	-
Feb.-Apr.	0.04326	-	0.01801	0.01136	-
Ave.	0.05210	0.01824	0.01712	0.01188	-

Table 14. Daily instantaneous mortality rates, i, of marked brown trout in seven, 100-m sections of Temple Fork; October, 1970-April, 1971

Period	Section	Age Group			
		O	I	II	III
Oct.-Dec.	I	-	-	-	-
	II	-	-	-	-
	III	-	-	0.01175	-
	IV	0.01175	-	-	-
	V	0.06209	0.02350	0.01350	0.01175
	VI	0.05586	-	0.01862	-
	VII	0.02611	-	0.00000	-
Dec.-Feb.	I	-	-	-	-
	II	-	-	-	-
	III	-	-	0.00000	0.00000
	IV	0.01260	-	0.01260	-
	V	-	0.01260	0.00737	-
	VI	0.04187	-	-	-
	VII	0.06301	-	0.01997	-
Feb.-Apr.	I	-	-	-	-
	II	-	-	-	-
	III	-	-	0.01136	0.00665
	IV	0.03409	-	-	-
	V	0.02273	-	0.01136	-
	VI	0.01801	-	0.01136	-
	VII	0.01136	-	-	-

A two-way analysis of variance was used to analyze the variations in mortality rates among age groups and sampling periods in marked brown trout (Table 15). This analysis demonstrated that the differences in mortality rates among age groups were significant at the 0.025 level but that there was no significant difference among the sampling periods.

Table 15. Abbreviated analysis of factors related to the mortality rates of marked brown trout in Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Age Group	3	0.0007851274	9.52*
Period	2	0.0000071903	0.09
Error	5	0.0000824696	

*Significant at the 0.025 level

The mortality rates (i) based on the estimated numbers of brown trout ranged from -0.00964 (Age Group III, February-April) to 0.04790 (Age Group O, February-April) (Table 16).

The $\underline{i}$ values based on the estimated number of brown trout in each of the 100-m sampling sections ranged from -0.02273 (Age Group III, Section V, Feb.-Apr.) to 0.06301 (Age Group O, Section VII, Feb.-Apr.) (Table 17).

Table 16. Daily instantaneous mortality rates, i, of estimated numbers of brown trout, Temple Fork; October, 1970-April, 1971

Period	Age Group				
	O	I	II	III	IV
Oct. -Dec.	0.01269	0.01862	0.01553	0.00000	0.04064
Dec. -Feb.	0.02207	0.04359	0.00523	0.01260	-
Feb. -Apr.	0.04790	-	0.01371	-0.00964	-
Ave.	0.02791	0.03067	0.01166	0.00060	-

Table 17. Daily instantaneous mortality rates, i of estimated numbers of brown trout in seven, 100-m sections of Temple Fork; October, 1970-April, 1971

Period	Section	Age Group			
		O	I	II	III
Oct. -Dec.	I	-	-	-	-
	II	-	-	-	-
	III	-	-	0.01862	-0.01175
	IV	0.00000	-	-0.01175	-
	V	0.06209	0.01862	0.02728	0.01175
	VI	0.01458	-	0.01862	-
	VII	-0.00226	-	-0.01175	-
Dec. -Feb.	I	-	-	-	-
	II	-	-	-	-
	III	-	-	-0.01260	0.01260
	IV	-0.02811	-	0.01260	-
	V	-0.02521	0.01260	0.0000	-
	VI	0.03100	-	-0.01260	-
	VII	0.06301	-	0.01260	-
Feb.-Apr.	I	-	-	-	-
	II	-	-	-	-
	III	-	-	0.01136	-0.01801
	IV	0.03409	-	-	-0.01136
	V	0.01801	-	0.00000	-0.02273
	VI	0.01801	-	0.01136	-
	VII	0.01136	-	-0.01136	-

Differences in mortality rates among age groups were significant at the 0.25 level. There was no significant difference (0.75 level) among sampling periods (Table 18).

Table 18. Abbreviated analysis of factors related to the mortality rates of estimated populations of brown trout, Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Age Group	3	0.0005531597	2.64*
Period	2	0.0001196123	0.57
Error	5	0.0002093489	

*Significant at the 0.25 level.

To determine the effects of snow cover and anchor ice on overwinter mortality rates in brown trout, a multiple regression line was calculated between mortality rates of marked brown trout and snow cover and anchor ice indices in only those sections that exhibited these phenomena. Due to the lack of sufficient data for all age groups, this analysis was only carried out for age groups O and II.

The regression for age group O brown trout was:

$Y = 0.01714 - 3.173 \times 10^{-8} X_1 + 2.069 \times 10^{-4} X_2$; where Y = mortality rate, i; X_1 = snow cover index; and X_2 = anchor ice index. The hypothesis test to determine the validity of prediction of X_1 and X_2 showed

that they were valid predictors at the 0.10 level (Table 19) but the hypothesis test to determine if the variate with the lower regression coefficient (snow cover index) contributed anything to the variance indicated that only the anchor ice index (X_2) contributed significantly to the variance of the mortality rates (Table 20).

Table 19. Abbreviated analysis of the effects of snow cover and anchor ice on mortality rates of marked Age Group O brown trout, Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Regression		0.000782962171	5.99*
Error		0.000130616307	

*Significant at the 0.10 level

Table 20. Hypothesis test to determine the predictability of the snow cover (X_1) and anchor ice (X_2) indices on mortality rates of marked Age Group O brown trout, Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom		
Regression	2	0.00078	6.00*
X_2	1	0.00156	11.92**
X_1 over X_2	1	0.00001	0.00
Error	4	0.00013	
Total	6	0.00035	

* Significant at the 0.10 level
**Significant at the 0.05 level

In marked Age Group II brown trout, the relationship of the snow cover index (X_1) and anchor ice index (X_2) to the mortality rates was: $Y = 0.00859 - 3.5449 \times 10^{-5} X_1 - 2.2118 \times 10^{-6} X_2$. The hypothesis test indicated that neither contributed significantly to the variance of the mortality rates (Table 21).

Table 21. Abbreviated analysis of the effects of snow cover and anchor ice on the mortality of marked Age Group II brown trout, Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Regression	2	1.98×10^{-4}	1.02*
Error	11	1.94×10^{-4}	

*Not significant ($\alpha = 0.50$)

Rainbow trout

Four age groups of rainbow trout were found in Temple Fork; O, I, II, and III. Rainbow trout of Age Group II were by far the most numerous, probably because approximately 3000 catchable rainbow trout are planted annually in the stream (Ware, Personal Communication).

Rainbow trout constitute 10, 24, 30, and 42 percent of all fish captured in October, December, February, and April (Table 22). However, this species made up 35, 57, 47, and 50 percent of the respective catches by weight.

Table 22. Estimated number, estimated weight (kg), percentage composition, and estimated standing crop (kg/ha) of rainbow trout, Temple Fork; October, 1970-April, 1971

Date	Number	% of Total Weight	Weight (kg)	% of Total Weight	Standing Crop (kg/ha)
Oct.	170	10	29.0	35	12.6
Dec.	190	24	28.3	57	12.3
Feb.	120	30	17.4	48	7.5
Apr.	104	42	16.3	50	7.1

Length-frequency distribution. The length-frequency distribution of rainbow trout were made on groups ranked in 10-mm total lengths (Figure 4).

Two Age Group O rainbow trout were captured in Temple Fork, both in the April sampling. Six Age Group I fish were captured throughout the study.

The majority of rainbow trout were of Age Group II. In October their total length ranged from 192 to 290 mm. In December the range was from 192 to 295 mm. In February the range was 202 to 302 mm, and in April, 174 to 282 mm.

A total of four Age Group II rainbow trout were captured; one in February and three in April. The one in February was 286 mm in length. One of the Age Group III rainbow trout caught in April was not measured. The lengths of the other two were 277 and 311 mm.

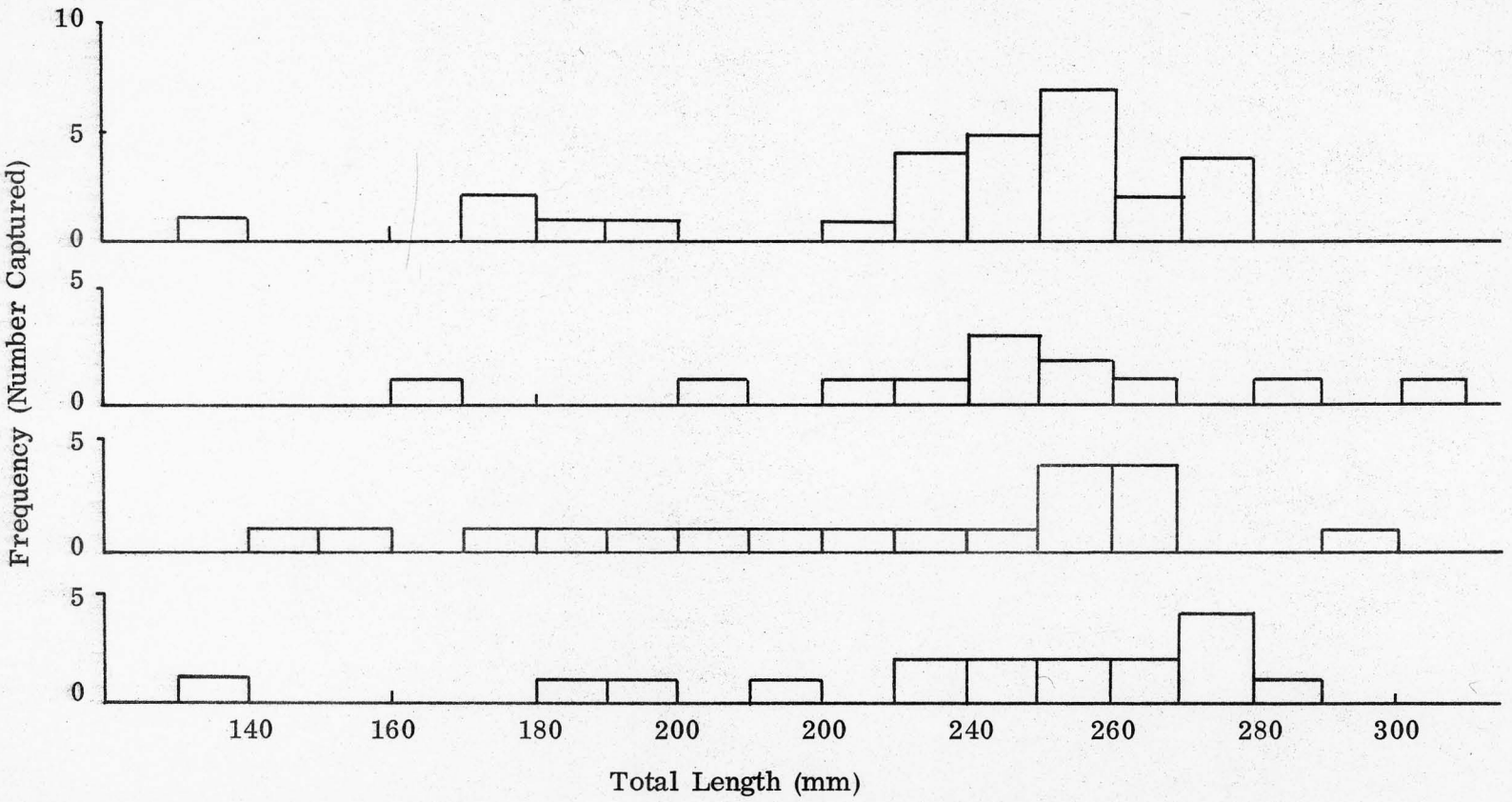

Figure 4. Length-frequency distribution of rainbow trout captured in Temple Fork, 1970-71.

Length-weight relationship. The length-weight relationship was calculated from the averages of groups of fish ranked in 10 mm total lengths of all fish captured in October, December, and February. Fish captured in April and weighed and measured were also used but for those which were not weighed, the calculated relationship was used to determine their weights. The calculated length-weight relationship was: Log W = 5.61521 + 3.26029 Log L.

Condition factors. K factors were calculated for all rainbow trout which were both weighed and measured using the reciprocal method of Carlander (1950). The means of rainbow trout of Age Group II in all sections were 1.11, 1.01, 0.89, and 1.03 for each of the samplings (Table 23).

Table 23. Mean K factors of Age Group II rainbow trout captured in Temple Fork; October, 1970-April, 1971 (Number of fish in parentheses)

Section	Month			
	October	December	February	April
I	-	-	-	-
II	1.26(3)	1.05(1)	-	-
III	1.21(5)	1.08(8)	0.97(3)	-
IV	0.96(2)	0.96(1)	-	-
V	1.00(1)	0.99(2)	0.93(3)	-
VI	0.93(2)	0.93(2)	0.85(2)	-
VII	1.06(3)	0.89(3)	0.75(2)	-
All	1.11(16)	1.01(17)	0.89(10)	1.03(47)

Movement of marked rainbow trout. Of 15 fish tagged in October, seven were recaptured in later samplings. Three had remained in the same stream unit, three had moved upstream in the same 100-m section, and one had moved downstream to a point approximately 10-m below the section of original capture.

Twenty-nine rainbow trout were tagged previous to the February sampling but only two tagged fish were captured in February. Both were captured 75 to 100-m upstream from where they had originally been captured.

Of 38 tagged rainbow trout five were recaptured in April. One of these had moved 50-m downstream from the point of original capture, two were captured in the same location, and one had moved approximately 20-m upstream.

Mortality. The estimated numbers of rainbow trout decreased from a high of 190 (for all age groups) in December to 104 in April, a decrease of 45 percent. Age Group II rainbow trout exhibited a decrease of 41 percent over the same time period.

Daily instantaneous mortality rates, i, of marked Age Group II rainbow trout were 0.01292, 0.02833, and 0.01293 for the three periods. The weighted average i of Age Group II rainbow trout was 0.01777. Age Group I rainbow trout were captured in limited numbers (Table 37) and the mortality of marked fish was calculated for the December to February Period only. The i was 0.01997.

The mortality rates of marked rainbow trout in each of the sections that they were captured in ranged from 0.00000 (Age Group II, Section III, October-December; and Age Group II, Section II, February-April) to 0.02521 (Age Group II, Section VII, December-February) (Table 24).

A two-way analysis of variance was used to analyze the variations in mortality rates among age groups and sampling periods in marked rainbow trout (Table 25). However, in both cases, the results of the analysis were significant at the 0.50 level.

The mortality rates, $\underline{i}$, based on the estimated numbers of rainbow trout ranged from -0.01175 (Age Group I, October-April) to 0.05536 (Age Group I, December-February) (Table 26).

The $\underline{i}$ values based on the estimated number of rainbow trout in each of the 100-m sampling sections ranged from -0.01260 (Age Group III, Section I, Dec.-Feb.) to 0.01862 (Age Group II, Section II, Oct.-Dec.) (Table 27).

The results of the analysis of variance to test the significance of the differences in mortality rates among age groups and sampling periods in the estimated populations of rainbow trout were similar to those of the marked fish. Again the differences in mortality rates were significant at the 0.50 level (Table 28).

To determine the effects of snow cover and anchor ice on overwinter mortality rates of Age Group II rainbow trout, a multiple regression line

Table 24. Daily instantaneous mortality rates, i, of marked rainbow trout in seven 100-m sections of Temple Fork; October, 1970-April, 1971

Period	Section	Age Group I	Age Group II	Age Group III
Oct.-Dec.	I	-	-	-
	II	-	0.00687	-
	III	-	0.00000	-
	IV	-	0.01862	-
	V	-	0.01175	-
	VI	-	0.01175	-
	VII	-	0.02350	-
Dec.-Feb.	I	-	-	-
	II	-	0.01260	-
	III	-	0.01836	-
	IV	0.01260	0.01260	-
	V	0.01260	0.01197	-
	VI	-	0.01197	-
	VII	-	0.02521	-
Feb.-Apr.	I	-	-	0.01136
	II	-	0.00000	-
	III	-	0.01136	-
	VI	-	-	-
	V	-	0.01801	-
	VI	-	0.01136	-
	VII	-	0.01801	-

Table 25. Abbreviated analysis of factors affecting the mortality of marked rainbow trout in Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Age Group	1	0.00010755	2.10*
Period	2	0.00006080	1.19*
Error	2	0.00005126	

*Significatn at the 0.50 level

Table 26. Daily instantaneous mortality rates, i, of estimated numbers of rainbow trout in Temple Fork; October, 1970-April, 1971

Period	Age Group I	Age Group II
Oct.-Dec.	-0.01175	-0.00103
Dec.-Feb.	0.05536	0.00965
Feb.-Apr.	0.02638	0.00101
Ave.	0.02263	0.00304

Table 27. Daily instantaneous mortality rates, i, of estimated numbers of rainbow trout in seven, 100-m sections of Temple Fork; October, 1970-April, 1971

Period	Section	Age Group I	Age Group II	Age Group III
Oct.-Dec.	I	-	-	-
	II	-	0.01862	-
	III	-	-0.00797	-
	IV	-0.01175	0.01175	-
	V	0.00000	-0.01175	-
	VI	-	0.00000	-
	VII	-	0.00000	-
Dec.-Feb.	I	-	-	-0.01260
	II	-	0.01260	-
	III	-	0.01783	-
	IV	0.01260	0.01260	-
	V	0.01260	-0.00737	-
	VI	-	0.00000	-
	VII	-	0.00737	-
Feb.-Apr.	I	-	-	0.01136
	II	-	-	-
	III	-	0.01801	-
	IV	-	-0.01136	-
	V	-	0.00665	-
	VI	-	0.01801	-
	VII	-	-0.00665	-

Table 28. Abbreviated analysis of factors affecting the mortality rates of estimated numbers of rainbow trout, Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Age Group	1	0.0006132216	1.51*
Period	2	0.0007566820	1.87*
Error	2	0.0004053791	

Table 29. Abbreviated analysis of the effects of snow cover and anchor ice on mortality rates, $\underline{i}$, of marked Age Group II rainbow trout in Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Regression	2	0.000002409	0.09*
Error	7	0.000026429	

*Not significant

was calculated between mortality rates of marked Age Group II rainbow trout and snow cover and anchor ice indices in only those sections that exhibited these phenomena. The relationship was: $Y = 0.0161256 - 4.7023 - 10^{-7}X_1 - 1.1098 \times 10^{-6}X_2$ where Y = mortality rate, $\underline{i}$; X_1 = snow cover index; and X_2 = anchor ice index. However, the hypothesis test Table 29) indicated that neither contributed significantly ($\alpha > 0.50$) to the variance of the mortality rates.

Cutthroat trout

Five age groups of cutthroat trout were found in Temple Fork, O, I, II, III, and IV. However, only three fish of Age Group IV were captured during the study.

Cutthroat trout constituted 24, 12, 25, and 43 percent of the numbers of fish captured in the October, December, February, and April samplings (Table 30). However, this species made up 19, 8, 32, and 29 percent of the catch by weight.

Table 30. Estimated number, estimated weight (kg), percentage composition, and estimated standing crop (kg/ha) of cutthroat trout, Temple Fork; October, 1970-April, 1971

Date	Number	% of Total Number	Weight (kg)	% of Total Weight	Standing Crop (kg/ha)
Oct.	390	24	15.5	19	6.7
Dec.	100	12	4.2	8	1.8
Feb.	110	25	11.8	32	5.1
Apr.	106	43	9.6	29	4.2

Length-frequency distribution. The length-frequency distributions of cutthroat trout were made on groups ranked in 25-mm total lengths (Figure 5).

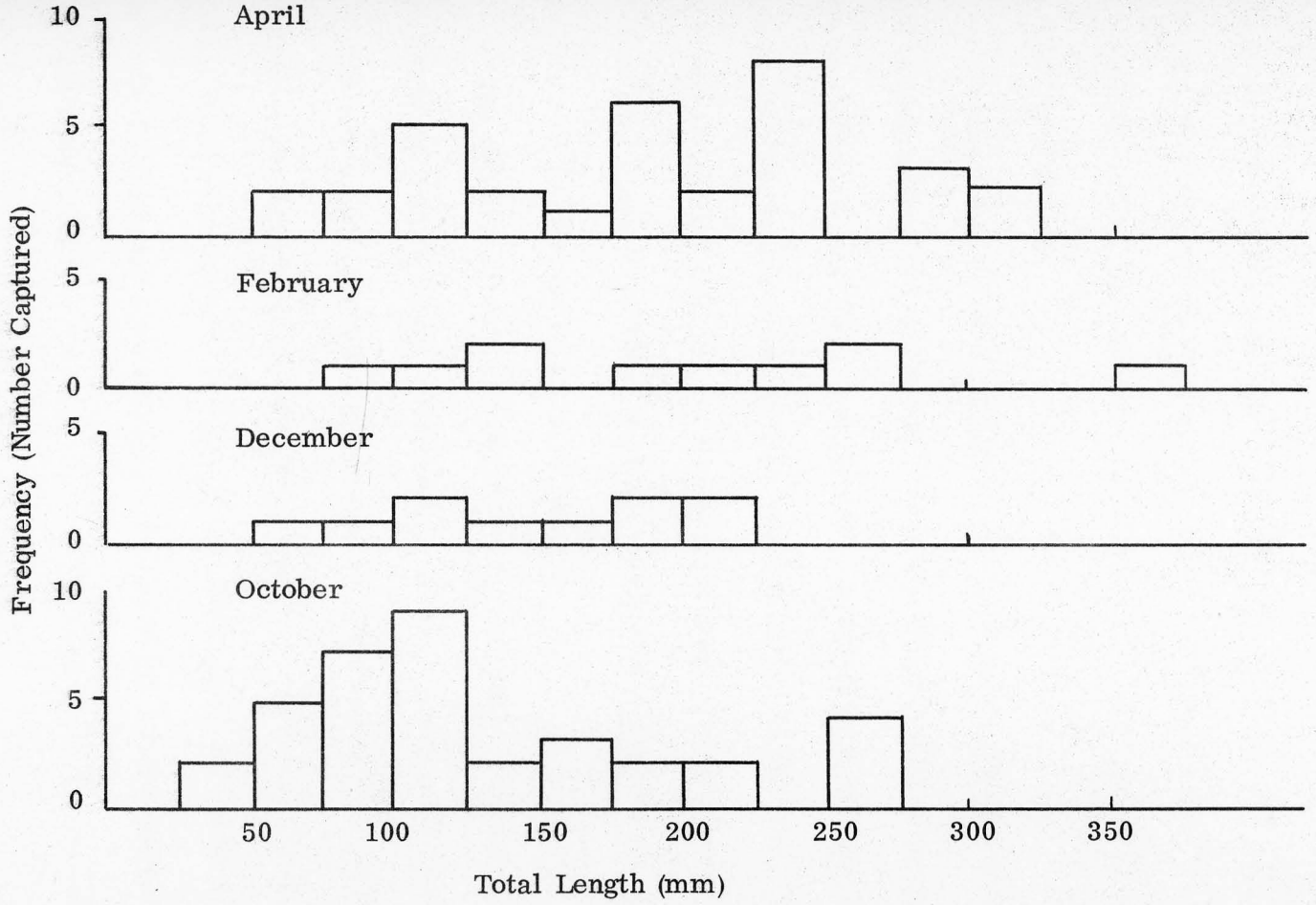

Figure 5. Length-frequency distribution of cutthroat trout captured in Temple Fork.

Age Group O cutthroat trout were the most numerous of this species during the October sampling when 18 were captured. These fish ranged in length from 41 to 112 mm. In December only three of these fish were captured and they ranged in length from 67 to 106 mm. One Age Group O cutthroat trout was captured in February and was 96-mm in length. Twelve were captured in April but two were not measured. The remaining ten were from 52 to 97 mm long.

Thirteen Age Group I cutthroat trout were captured in October and ranged in length from 105 to 199 mm. Four were captured in December and were 114 to 176 mm long. The February sampling included four Age Group I cutthroat trout which ranged in length from 121 to 168 mm. Fifteen were captured in April and were 109 to 199 mm long. Of the 23 unmeasured cutthroat trout captured in April, seven were considered to be Age Group I on the basis of the percent captured and aged.

The four Age Group II cutthroat trout captured in October ranged from 180 to 257 mm in length. Three were captured in December and were 196 to 219 mm long. Only two Age Group II cutthroat trout were captured in February and their lengths were 199 and 207 mm. Ten Age Group II cutthroat trout were captured in April ranged in length from 125 to 231 mm. Four of the 23 cutthroat trout not measured or aged in April were considered to be Age Group II fish.

Four Age Group III cutthroat trout were captured in October and ranged in length from 215 to 266 mm. No Age Group III cutthroat trout were captured in December and only two were captured in February, both 246 mm long. Age Group II fish were the most numerous in April when 19 were captured. They ranged in length from 202 to 303 mm. Eight of the unaged and unmeasured cutthroat trout were considered to belong to Age Group III.

No Age Group IV cutthroat trout were captured in the October and December sampling and only two were captured in February. They were 273 and 358 mm long. However, four were captured in April and ranged from 289 to 307 mm. Two unaged and unmeasured cutthroat trout captured in April were considered to belong to Age Group IV.

Length-weight relationship. The length-weight relationship was calculated on the averages of groups of cutthroat trout ranked in 25 mm total lengths for all fish captured in October, December, and February. Fish captured in April and weighed and measured were also used but for those which were only measured, the calculated relationship was used to determine their weights. The calculated length-weight relationship was: $\text{Log } W = -4.74491 + 2.88820 \text{ Log } L$.

Condition factors. K factors were calculated for all cutthroat trout which were both weighed and measured using the reciprocal method of Carlander (1950). The mean K factors ranged from 0.72 (Age Group O, February) to 1.78 (Age Group O, December) (Table 31).

Table 31. Mean condition factors of cutthroat trout captured in seven 100-m sections of Temple Fork; October, 1970-April, 1971. (Number of fish in parentheses)

Age Group	Section	Month			
		October	December	February	April
O	I	-	-	-	-
	II	-	-	-	-
	III	-	-	-	-
	IV	1.02(4)	-	-	-
	V	-	-	-	-
	VI	1.00(10)	1.78(2)	-	-
	VII	1.00(4)	1.12(1)	0.72(1)	-
	All	1.01(18)	1.56(3)	0.72(1)	1.13(10)
I	I	-	-	-	-
	II	-	-	-	-
	III	1.13(1)	0.84(1)	-	-
	IV	1.02(6)	0.87(1)	-	-
	V	1.22(2)	-	-	-
	VI	-	0.79(1)	-	-
	VII	0.95(2)	-	-	-
	All	1.05(11)	0.83(3)	-	1.05(15)
II	1	-	-	-	-
	II	-	-	-	-
	III	1.22(1)	1.00(1)	0.96(1)	-
	IV	0.84(1)	-	-	-
	V	1.06(1)	1.02(2)	0.91(1)	-
	VI	0.91(2)	-	-	-
	VII	-	-	-	-
	All	1.02(4)	0.97(4)	0.94(2)	1.05(10)
III	I	-	-	0.94(2)	-
	II	1.07(2)	-	-	-
	III	-	-	-	-
	IV	0.95(1)	-	-	-
	V	0.98(1)	-	-	-
	VI	-	-	-	-
	VII	-	-	-	-
	All	1.02(4)	-	0.94(2)	1.05(19)
IV	III	-	-	1.02(2)	-
	All	0.99(37)	1.11(10)	1.30(5)	1.07(54)

Movement of tagged cutthroat trout. Of 35 cutthroat trout marked in October, only four were recovered and all were found in the same section in which they were originally captured. In February two previously marked fish were captured and again they were in the same section as their first capture. Three marked cutthroat trout were captured in the April sampling. One was captured in the section of original capture, one moved approximately 800 m upstream, and one approximately 900 downstream.

Mortality. The estimated numbers of cutthroat trout decreased from a total (for all age groups) of 390 in October to 106 in April, a decrease of 73 percent. However, there was a 90 percent decrease in numbers of Age Group O cutthroat trout, a 78 percent decrease in Age Group I, a 55 percent decrease in Age Group II, and a 12 percent decrease in Age Group III.

Daily instantaneous mortality rates, i, of marked cutthroat trout ranged from 0.00000 (Age Group III, December-February) to 0.04699 (Age Group O, December-February) (Table 32).

The i values of marked cutthroat trout in each of the sampling sections in which they were found ranged from 0.00000 to 0.03724 (Table 33).

A two-way analysis of variance was used to analyze the variations in mortality rates among age groups and sampling periods in marked cutthroat trout (Table 34). This analysis demonstrated that the differences in mortality rates among age groups were not significant ($\alpha = 0.50$,

Table 32. Daily instantaneous mortality rates, $\underline{i}$, of marked cutthroat trout in Temple Fork; October, 1970-April, 1971

Period	Age Group				
	O	I	II	III	IV
Oct.-Dec.	0.04699	0.02202	0.02342	0.02350	-
Dec.-Feb.	0.02521	0.02521	0.01999	0.0000	-
Feb.-Apr.	0.01136	0.02638	0.01801	0.01801	0.01801
Ave.	0.02773	0.02454	0.02046	0.01420	-

Table 33. Daily instantaneous mortality rates, $\underline{i}$, of marked cutthroat trout in seven, 100-m sections of Temple Fork; October, 1970-April, 1971

Period	Section					
Oct.-Dec.	I	-	-	-	-	-
	II	-	-	-	0.01862	-
	III	-	0.00000	0.00000	-	-
	IV	0.02728	0.03037	-	0.01175	-
	V	-	0.01862	0.00000	0.00000	-
	VI	0.03724	-	0.01862	-	-
	VII	0.02350	0.02350	-	-	-
Dec.-Feb.	I	-	-	-	-	-
	II	-	-	-	-	-
	III	-	0.00000	0.01260	-	-
	IV	-	0.01260	0.01260	-	-
	V	-	-	0.01260	0.00000	-
	VI	0.01197	0.01260	-	-	-
	VII	0.01260	-	-	-	-
Feb.-Apr.	I	-	-	-	0.01136	-
	II	-	0.01136	-	-	-
	III	-	0.01136	0.01136	-	0.01801
	IV	-	0.01136	-	-	-
	V	-	-	0.01136	0.00000	-
	VI	-	-	-	-	-
	VII	0.01136	0.01136	-	-	-

Table 34. Abbreviated analysis of factors related to the mortality of marked cutthroat trout in Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Square	F
Age Group	3	0.0001137822	1.08*
Period	2	0.0001785234	1.70*
Error	6	0.0001050225	

*Significant at the 0.50 level

F = 1.08) and that differences in mor tality rates among sampling periods were not significant (α = 0.50, F = 1.70).

The mortality rates, $\underline{i}$, based on the estimated numbers of cutthroat trout ranged from -0.00837 (Age Group III, February-April) to 0.06294 (Age Group II, October-December) (Table 35).

The $\underline{i}$ values based on the estimated number of cutthroat trout in each of the 100-m sampling sections ranged from -0.01260 (Age Group I; Section II and VII, December-February; Age Group II, Section III, December-February) to 0.03298 (Age Group I, Section IV, October-December) (Table 36).

Differences in mortality rates, $\underline{i}$, among sampling periods in estimated numbers of cutthroat trout were significant at the 0.25 level (F = 2.98) but differences among age groups were not significant (α = 0.50, F = 1.62) (Table 37).

Table 35. Daily instantaneous mortality rates, i, of estimated numbers of cutthroat trout in Temple Fork; October, 1970-April, 1971

Period	Age Group				
	O	I	II	III	IV
Oct.-Dec.	0.02940	0.01998	0.00488	0.06294	-
Dec.-Feb.	0.01998	0.00523	0.00737	0.05536	-
Feb.-Apr.	-0.00770	0.00529	0.00173	-0.00837	0.02273
Ave.	0.01351	0.01022	0.00457	0.02999	-

Table 36. Daily instantaneous mortality rates, i, of cutthroat trout in seven, 100-m sections of Temple Fork; October, 1970-April, 1971

Period	Section	Age Group				
		O	I	II	III	IV
Oct.-Dec.	I	-	-	-	-	-
	II	-	-	-	-	-
	III	-	-	-	-	-
	IV	0.02728	0.03298	-0.01175	0.01175	-
	V	-	0.01862	-	-0.01175	-
	VI	0.02549	-0.01175	0.01862	-	-
	VII	0.02350	0.02350	-	-	-
Dec.-Feb.	I	-	-	-	0.01927	-
	II	-	-0.01260	-	-	-
	III	-	0.01260	-0.01260	-	-
	IV	-	0.00000	0.01260	-	-
	V	-	-	0.01260	-	-
	VI	0.01927	0.01260	-	-	-
	VII	0.0000	-0.01260	-	-	-
Feb.-Apr.	I	-	-	-	0.01801	-
	II	-	0.01136	-	-0.01136	-
	III	-	0.01136	0.01136	-	0.01136
	IV	0.01136	-0.01136	0.00000	-0.001136	-
	V	-	-	0.01136	-	-
	VI	-	-	-	-	-
	VII	0.01136	0.00000	-0.001136	-	-0.01136

Table 37. Abbreviated analysis of factors related to the mortality rates of estimated numbers of cutthroat trout, Temple Fork; October, 1970-April, 1971

Source	Degrees of Freedom	Mean Squares	F
Age Group	3	0.000592743966	1.62*
Period	2	0.001091761300	2.98**
Error	6	0.000366693216	

* Significant at the 0.50 level
**Significant at the 0.25 level

Tag loss

Three brown trout were recaptured with evidence of tag loss during the study. Because the dart-tag used in this study leaves a small wound that is easily recognizable, these fish were retagged and were considered in the estimates of tagged fish recaptured. Two rainbow and two cutthroat trout were also captured with evidence of tag loss. These fish were treated in the same manner as the brown trout.

DISCUSSION

Overwinter mortality of trout in streams has generally been associated with severe environmental conditions such as anchor ice (Maciolek and Needham, 1951; Needham, Moffett, and Slatter, 1945; and Needham and Slatter, 1944), falling snow banks (Needham and Slatter, 1944), and water temperatures (Hunt, 1969; and Nielson, Reimers, and Kennedy, 1957). In Temple Fork of the Logan River during the winter of 1970-1971 the only significant ($\alpha = 0.05$) environmental factor affecting mortality rates was anchor ice. The affect on Age Group O brown trout was significant ($\alpha = 0.50$) but the affect on Age Group II was not. There were insufficient numbers of brown trout of other age groups to analyze the affects of these factors on Age Groups I, III, and IV.

Anchor ice is known to scour the bottoms of streams when breaking up. In Convict Creek (Maciolek and Needham, 1951) mortality of trout attributed to anchor ice was primarily due to the blockage of side-channel stream flow. This condition was not noted in Temple Fork as the lower sections of the creek in which anchor ice formed did not have any side-channels and the sections with side-channels were not subject to anchor ice formation. It was assumed that the effect of anchor ice on trout in Temple Fork was the increased stress imposed on the fish by the chunks of anchor

ice which wash down the stream when the temperatures warm enough for it to begin breaking up.

Neither snow cover nor anchor ice was a significant factor affecting the mortality rates of Age Group II rainbow trout. Other age groups of this species were not captured in sufficient numbers to permit an analysis.

The analysis of the effects of snow cover and anchor ice was not performed for cutthroat trout due to an insufficient number of fish captured in the sampling sections. However, in the analysis of estimated numbers of cutthroat trout, the sampling periods were a significant ($\alpha = 0.25$) factor on mortality rates. Thus, there may be other environmental factors influencing the mortality rates.

It was not known if snow slides had formed snow dams with resultant fluctuations in stream flow of Temple Fork; a condition which Maciolek and Needham (1955) reported to have caused mortalities in Convict Creek.

Needham, Moffett, and Slatter (1945) found that overwinter mortality in Convict Creek was highest in large brown trout and Needham (1947) reported that mortality was approximately the same regardless of size. In Temple Fork the younger age groups of brown trout exhibited the highest mortality rates. Age Group was shown to be a significant factor affecting the mortaility rates of both marked ($\alpha = 0.025$) and estimated numbers ($\alpha = 0.25$).

Age was not a significant factor affecting the mortality rates of rainbow trout. This lack of apparent affect may have been due to the fact

that the vast majority of rainbow trout captured were of Age Group II.

Age was not a significant factor affecting mortality rates in cutthroat trout although the mortality rates of marked Age Group O and I fish were slightly higher than the rates of Age Groups II, III, and IV.

The April sampling of Temple Fork took place during a period of relatively high flow and a few areas were not sampled due to extremes in the flow making the shocking operations hazardous. The high flow and turbid water probably resulted in a low estimate of population numbers and a bias toward the larger individuals which were not visible. This in turn may have resulted in a higher mortality estimate in the younger age groups.

Recapture studies in Temple Fork and the Logan River indicated that there was little movement in any of the three species. Two tagged Age Group II brown trout and one tagged Age Group II rainbow trout were captured in the Logan River during the April sampling. However, movement of trout out of Temple Fork was not considered in the calculations of mortality but may have been one of the reasons for the high mortality rates in older age groups. No evidence of movement of Age Group O out of Temple Fork was found in April and it was assumed that the high mortality rates of the Age Group O fish, and particularly the Age Group O brown trout were due to the conditions in Temple Fork.

Although the fish captured in February and held in live cages did not show any ill-effects of the sampling procedures, three brown trout, two

rainbow trout, and two cutthroat trout captured curing the regular collections died during handling. However, a low mortality might be expected in fish exposed to the stress of shocking and handling. This may be especially true in the case of large fish which may receive a greater voltage than the smaller ones (Sigler, 1969; and Sullivan, 1956). Studies by Maxfield, Lander, and Liscom (1971) with pulsating direct current of the type produced by my equipment demonstrated that the survival of Age Group O and I rainbow trout was not affected by the shock. However, Bouch and Ball (1966) found that shocked fish showed signs of hyperexcitability and prolonged fasting.

Horak (1969) demonstrated that the removal of fins other than the caudal fin of hatchery-reared rainbow trout had no significant affect on stamina. In studies with yellow perch (Perca flavescens) Strobo (1972) found that the plastic dart tag did not increase mortality but that some wound formation was caused by the design of the tag. The wounds did not seem to adversely affect the perch.

Although the fishing season was open until November 30, 1970, no anglers were observed during the months of October and November, 1970 and angling mortality was considered to be insignificant.

Overwinter mortality of trout in Temple Fork during the winter of 1970-1971 was higher than the mortality reported by other investigators. Although there was little statistical correlation of mor tality with environmental factors, the data suggest that the stress imposed on the fish by severe environmental conditions was an important factor in causing the

high mortalities. The highest anchor ice and snow cover indicies were in the December to February Period coincident with the highest mortality rates in marked fish of all three species; indicating that the severe conditions had an effect on trout mortality in Temple Fork. Brown and rainbow trout condition factors also exhibited the greatest decrease from December to February indicating that the environmental factors adversely effected the condition of the fish.

CONCLUSIONS

Brown trout experienced the highest mortality rates found in Temple Fork of the Logan River during the winter of 1970-1971. Estimated numbers of brown trout of all age groups decreased by 97 percent during the study. Daily instantaneous mortality rates, $\underline{i}$, ranged from 0.01136 to 0.06796 in marked fish and from -0.00964 to 0.04790 in estimated numbers. Mortality rates of younger fish were significantly higher in both marked ($\alpha = 0.025$) and estimated numbers ($\alpha = 0.25$). Although anchor ice was a significant factor ($\alpha = 0.05$) affecting mortality rates of Age Group O brown trout, it was not significant in the case of Age Group II.

Estimated numbers of rainbow trout of all age groups decreased by 45 percent during the study. Daily instantaneous mortality rates, $\underline{i}$, of rainbow trout ranged from 0.01292 to 0.02833 in marked fish and from -0.01175 to 0.05536 in estimated numbers. Mortality rates were not significantly different among age groups or sampling periods and there was no significant correlation of mortality of Age Group II fish with anchor ice or snow cover.

The estimated numbers of all age groups of cutthroat trout decreased by 73 percent during the study. Daily instantaneous mortality rates, $\underline{i}$, of marked cutthroat trout ranged from 0.00000 to 0.04699.

For estimated numbers the rates ranged from -0.00837 to 0.06294. Mortality rates of estimated numbers of cutthroat trout were significantly (α = 0.25) different among sampling periods.

Mortality rates during the February to April sampling may have been lower than was actually reported since the April sampling was done during a period of high and turbid flow. This may especially be true for smaller fish which were more difficult to observe in the turbid waters.

While investigators (Dell, 1968; Horak, 1969; and Strobo, 1972) have found little mortality associated with the sampling procedures used in this study, none of the previous investigations were carried out during periods of severe environmental conditions. The fact that the operations on fish in Temple Fork were done during a time of year that puts a great strain on fish may have caused some increase in the natural mortality.

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APPENDIX

Table 38. Numbers of brown trout captured in seven 100-m sections of Temple Fork; October, 1970-April, 1971

Date	Section	Age Group				
		O	I	II	III	IV
October	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	2	1	0
	IV	1	0	0	0	0
	V	38	3	5	1	1
	VI	26	0	2	0	0
	VII	28	0	0	0	0
December						
	I	**	**	**	**	**
	II	0	0	0	0	0
	III	0	0	0	2	0
	IV	1	0	1	0	0
	V	0	1	1	0	0
	VI	11	0	0	0	0
	VII	32	0	2	0	0
February						
	1	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	1	1	0
	IV	7	0	0	0	0
	V	3	0	1	0	0
	VI	2	0	1	0	0
	VII	1	0	0	0	0
April						
	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	3	0
	IV	0	0	0	1	0
	V	1	0	1*	3*	0
	VI	0	0	0	0	0
	VII	0	0	1	0	0

* Captured trout neither weighed nor measured; age based on percentage captured and aged.

**Not sampled due to heavy snows.

Table 39. Numbers of rainbow trout captured in seven 100-m sections of Temple Fork; October, 1970-April, 1971

Date	Section	Age Group			
		O	I	II	III
October	I	0	0	0	0
	II	0	0	3	0
	III	0	0	5	0
	IV	0	0	2	0
	V	0	1	1	0
	VI	0	0	2	0
	VII	0	0	3	0
December					
	i	*	*	*	*
	II	0	0	1	0
	III	0	0	8	0
	IV	0	1	1	0
	V	0	1	2	0
	VI	0	0	2	0
	VII	0	0	3	0
February					
	I	0	0	0	1
	II	0	0	0	0
	III	0	0	3	0
	IV	0	0	0	0
	V	0	0	3	0
	VI	0	0	2	0
	VII	0	0	2	0
April					
	I	0	0	0	0
	II	0	0	0	0
	III	0	0	1	0
	IV	0	0	1	0
	V	0	0	2	0
	VI	0	0	0	0
	VII	0	0	3	0

*Not sampled due to heavy snows.

Table 40. Numbers of cutthroat trout captured in seven 100-m sections of Temple Fork; October, 1970-April, 1971

Date	Section	Age Group				
		O	I	II	III	IV
October	I	0	0	0	0	0
	II	0	0	0	2	0
	III	0	1	1	0	0
	IV	4	7	0	1	0
	V	0	2	1	1	0
	VI	10	0	2	0	0
	VII	4	3	0	0	0
December						
	1	*	*	*	*	*
	II	0	0	0	0	0
	III	0	2	0	0	0
	IV	0	1	1	0	0
	V	-	-	2	0	0
	VI	2	1	0	0	0
	VII	1	0	0	0	0
February						
	I	0	0	0	2	0
	II	0	1	0	0	0
	III	0	1	1	0	0
	IV	0	1	0	0	0
	V	0	0	1	0	0
	VI	0	0	0	0	0
	VII	1	1	0	0	0
April						
	I	0	0	0	0	0
	II	0	0	0	1	0
	III	0	0	0	0	0
	IV	1	2	1	1	0
	V	0	0	0	0	0
	VI	0	0	0	0	0
	VII	0	1	1	0	1

*Not sampled due to heavy snows.

Table 41. Numbers of brown, rainbow, and cutthroat trout captured during the April, 1971 Sampling of Temple Fork

Species	Age Group				
	O	I	II	III	IV
Brown	5	0	10	14	0
Rainbow	2	3	72	3	0
Cutthroat	12	22	14	27	6

Table 42. Estimated numbers of brown, rainbow, and cutthroat trout in Temple Fork in April, 1971

Species	Age Group				
	O	I	II	III	IV
Brown	7	0	13	18	0
Rainbow	2	4	94	4	0
Cutthroat	16	29	18	35	8

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